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SMITHSONIAN ASTROPHYSICAL OBSERVATORY

Reference System Bulletin No. 1

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301-056

Keeping up with the times

In 1658 the King of Spain offered 60 000 ducats to "the discoverer of longitude." One hundred and twenty-five years later the problem had still not been solved, so the British government came forward with an offer of its own: 20 000 pounds. Although scientists of that period realized the key to determining longitude involved a combination of astronomical observations and time measurements, no clock was capable of keeping good time on the high seas. Then, in 1735, John Harrison, an Englishman, presented a working model of his temperature-compensated pendulum clock to the Board of Longitude. After many trial demonstrations and several models later, Harrison received the full reward.

Harrison's clock kept time to about III seconds a day. Since then there have been significant advances in timekeeping technology, culminating with today's devices based on atomic phenomena. Navigators using Harrison's clock were soon to discover that different locations on the earth yielded different Universal Time values—a result of the then unknown wobbling of the earth on its axis. A second correction was made in 1935, when seasonal changes in the earth's rotational rate were discovered. Consequently, when one talks of Universal Time, he should specify the UT scale: UT0, John Harrison's time scale; UT1, a scale that takes into account the earth's wobble; UT2, a scale that corrects for variations in the earth's rotation; or UTC, the new Coordinated Universal Time System.

Jespersen, Fey—"Time-telling" techniques

IEEE spectrum MAY 1972

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SMITHSONIAN ASTROPHYSICAL OBSERVATORY

Reference System Bulletin No. 1

1. INTRODUCTION

The Smithsonian Astrophysical Observatory (SAO) reference system has many applications (see Veis, 1966). Documentation is necessary to support communications between those who gather data and those who process data. The reference system involves timing, scale, coordinate systems and their transformations, and observations of the rotation of the Earth.

The sources and the users of these data are many, and this bulletin is intended as a vehicle to document the data and disseminate changes. The bulletin will be issued regularly and will update and extend station-time data, UT1, and polar-motion data used in data reduction and analysis. Other information, such as change in location of a station or improvements in survey coordinates, will be included. In this way, all users of SAO data will have the most up-to-date information for data reduction and analysis.

2. DESCRIPTION OF THE SYSTEM

Two timing-related activities are performed in the Satellite-Tracking Program: (1) Monitoring the relationship between different time scales and (2) correcting observational data for proper epoch.

In the following Time Flow Chart (Fig. 1), the sources of timing information are shown at the top and the final users of the data at the bottom. The time corrections

This bulletin is the result of a joint effort of STADAD, the Data Services Division, and the Satellite Geophysics Department under the guidance of E. M. Gaposchkin.

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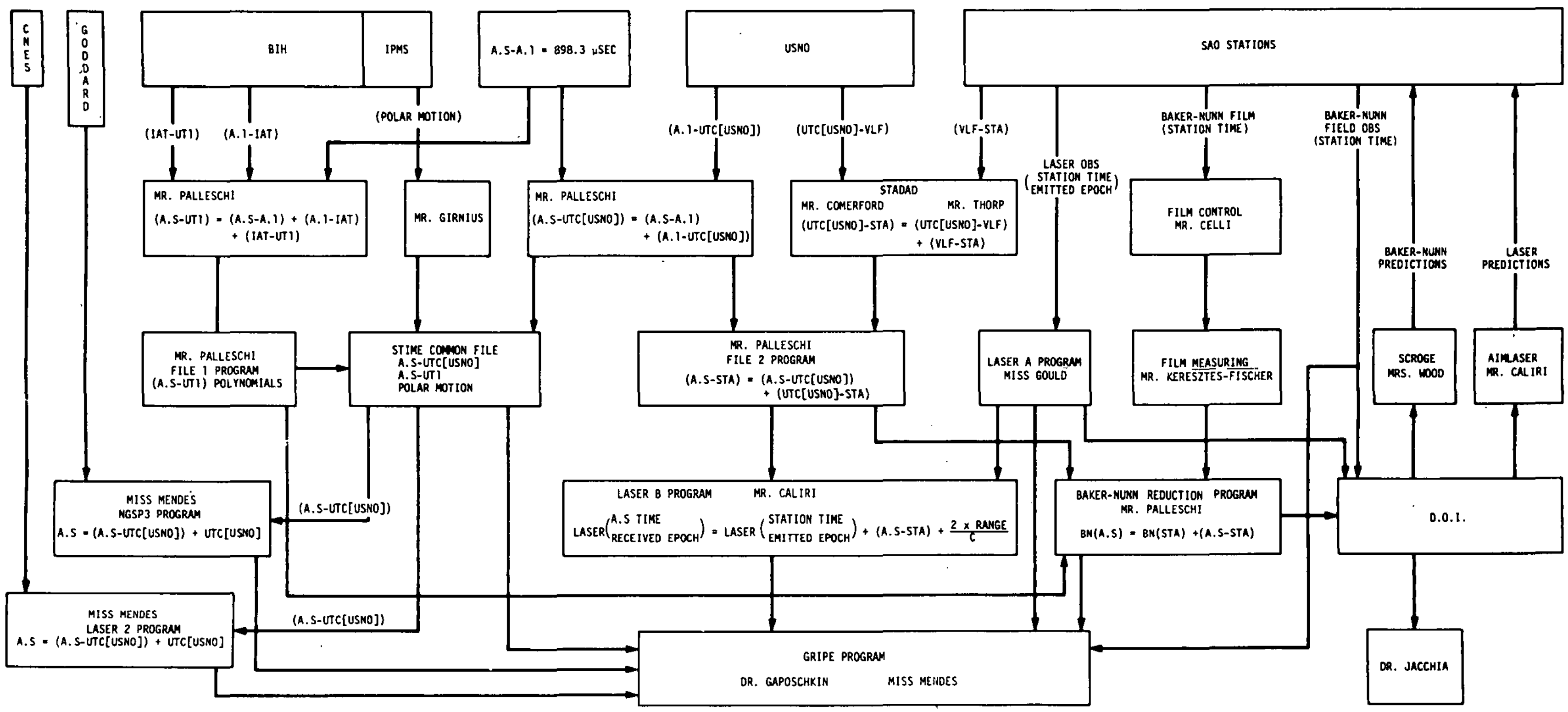
FIGURE 1. TIME FLOW CHART



performed within intermediate blocks are shown as equations. Some of the blocks do not involve any timing corrections and have been shown only to give a more complete picture of the overall processing of satellite observations at SAO. The DOI and GRIPE blocks represent complicated programs, and no attempt has been made to show details of their operation.

2.1 Timing (Epoch)

Epoch time is maintained at each station by use of the EECo precision-time system and is kept with reference to UTC as maintained by the United States Naval Observatory (USNO). A portable clock is used to set the station clock. Time is then maintained by referencing the frequency of a 5-MHz crystal oscillator to a known frequency broadcast by one of the various VLF stations. Each observing station maintains an estimate of its timing uncertainty in two ways:

1) The accuracy of the original clock set from a portable clock is expressed as an uncertainty (usually ±5 μsec). If the main channel has to be reset to one of the backup channels, another uncertainty (usually ±5 μsec) is added.

2) The extent of the deviation is determined by comparing the phase of the VLF signal with that of the oscillator signal. Each station steers or guides its oscillator to keep its time-drift uncertainty as small as possible (usually ±50 μsec).

Two sets of time corrections are added to the data in order to obtain time approximating UTC as kept by USNO. One set consists of corrections of hours, minutes, seconds, or parts of seconds when a failure has occurred in the station clock and when this has created errors in the recorded epoch. These corrections are confirmed at the station by referring to the alternate timekeeping channel and WWV time signals. If all channels fail and no backup time reference is available, a reset is necessary and a portable-clock trip to the station is made. The second correction, generated in Cambridge, consists of computations based on values for the phase difference between the average VLF phase value for a time reporting period (usually a month) and the phase value of the VLF signal at the time the clock is set. These corrections, determined from data published in USNO time-service bulletins, are generally less than 20 μsec.

A new time reporting procedure has been initiated to reduce the net timing uncertainty by recovering the portion due to oscillator drift. Section 2.2 describes the full extent of the STADAD time calculations.

Two files of time corrections are maintained by the Data Services Division at SAO. The first gives the difference between A.S and UT1, and the second, the difference between A.S and the clocks at the observing stations. The time system A.S is related to UTC(USNO) by the expression

$$A.S - UTC(USNO) = 6\overset{s}{.}140768 + 0.002592000(T - 39856.0)$$

for the period February 1, 1968, to January 1, 1972; T is the time in Modified Julian Days; 39856.0 is January 1.0, 1968; and the difference is given in seconds. The A.S - A.1 difference is about 0.8983 msec.

UT1 data are obtained from "Circular D," published monthly by the Bureau International de l'Heure (BIH). Values of UT1 - UTC(BIH) and AT - UTC(BIH) are listed at 5-day intervals. The difference A.S - AT is currently 35.3 msec. A.S - UT1 is calculated by the relation

$$A.S - UT1 = (A.S - AT) + [AT - UTC(BIH)] - [UT1 - UTC(BIH)] \quad .$$

A second-order polynomial is fitted to the A.S - UT1 values, and the coefficients are punched on cards. Usually, each polynomial covers a 50-day period. If the values change too rapidly, the interval can be reduced to 25 days.

The difference between the station clocks and UTC(USNO) is recorded by STADAD as described. The corrections are applied to the A.S - UTC(USNO) difference to obtain the correction from the station clock to A.S time. Cards are punched giving these corrections as a series of straight-line segments specifying the values of the corrections at the beginning and end of each interval. A new card must be used whenever there is a gap, discontinuity, or change of slope in the time correction.

2.2 STADAD Timing Corrections

A standardized format for reporting time differences and comparisons has been set down by USNO in their Time Service Announcement, Series 14, No. 2. This convention has been accepted by the international timing community and is the guideline STADAD uses to report its time and frequency corrections.

The time presented on the Baker-Nunn film and laser-observation records is the time carried by the station clock. An attempt is made to relate the time of all SAO station clocks to USNO time in Washington, D.C., by making portable-clock trips and by tracking VLF signals. The net correction that STADAD presents is, therefore, an attempt to reduce the known time errors in the satellite observation data so that the corrected time will correspond as closely as possible to UTC(USNO). The ambiguity that remains is expressed in the time-uncertainty terms.

The following abbreviations are used in detailing the time corrections:

STAT – Station time as presented in the data.

USNO – UTC(USNO).

OTV – "On time value," the reference phase value that the station uses in tracking the EECo clock time relative to the received VLF signal.

VLF – Phase of the very low frequency radio source.

The various components that make up the net correction are listed below with the corresponding entry names as they appear on the time-correction forms. The sum of all the entries gives the net correction.

$STAT_D$ - OTV

OTV - $USNO_O$

$USNO_O$ - VLF_O

VLF_O - VLF_D

VLF_D - $USNO_D$

STAT - $USNO_D$

The interpretation is as follows:

STAT - OTV – The daily drift of the station clock as measured in relation to the VLF monitor is recorded.

OTV - $USNO_O$ – The results of clock comparisons produce measures of time difference between the station clock, when set to its OTV, and the time held by USNO.

$USNO_O$ - VLF_O – The VLF station has a certain initial phase relationship to USNO (the change will be expressed in the next two terms).

VLF_O - VLF_D – A station tracks one particular cycle of the frequency transmitted by one VLF station, and if any change is made by the timing engineer in either the tracking cycle or the station being tracked, then the result is recorded as VLF.

VLF_D - $USNO_O$ – Daily records are kept relating the phase relationship of the transmitted VLF frequencies to USNO time standards.

$STAT_D$ - $USNO_D$ – The day-to-day time difference between the station clock and UTC (USNO) is obtained by summing all the previously mentioned terms.

The net time correction obtained from our time-reduction form is identified as STAT - USNO. For this to be applied to the Baker-Nunn and laser observations, the convention for reporting time differences must be followed:

STAT	=	station time
<u>-(STAT - USNO)</u>	=	<u>-(net correction)</u>
USNO	=	time according to USNO

The only deviation from this format comes when clock jumps occur. These cannot be described in the terms that we use to report the clock drift and, therefore, must be applied in addition to the STAT - USNO drift correction. The correction is given in the form of an instruction to ADD or SUBTRACT time from the figures on the observation forms or file. Since these corrections occur very infrequently and since

they cannot be handled in the drift correction, these instructions must be given in word comments that accompany the time drift reduction form.

Data collected before September 1972 received all corrections in the word-instruction form just described. These corrections accounted for the OTV - $USNO_O$, $USNO_O$ - VLF_O, VLF_O - VLF_D, and VLF_D - $USNO_D$ correction components but did not include the effects of the station-oscillator drift component $STAT_D$ - OTV. The time-uncertainty term, mentioned in Section 2. 1, was therefore used to encompass the clock-comparison errors and the amount of time-offset the station clock sustained in comparison to its VLF-generated on-time reference position as a result of oscillator frequency drift $STAT_D$ - OTV. The net time uncertainty has been reduced by a factor of two or three by the new reporting procedure.

2.3 Summary

The time of the satellite observations is corrected by applying the word message instructions to ADD or SUBTRACT a certain amount of time in the rare situation when a time jump has affected the station clock. The observation times must always be corrected for the drift in the station clock and the time-offsets detected by portable-clock comparisons or VLF phase calculations. This is performed by subtracting the correction known as STAT - USNO from the observed times. Data for that correction term are supplied by STADAD to Data Services:

STAT	=	time on data
-(STAT - USNO)	=	-(correction as given)
USNO	=	time corrected to USNO

3. DATA

Baker-Nunn Station Identification

Site Number	Location
9002	Olifantsfontein, South Africa
9004	San Fernando, Spain
9006	Naini Tal, India
9007	Arequipa, Peru
9012	Maui, Hawaii
9021	Mt. Hopkins, Arizona
9023	Island Lagoon, Australia
9025	Dodaira, Japan
9028	Debre Zeit, Ethiopia
9029	Natal, Brazil
9030	Dionysus, Greece

In the data that follow, it will be noted that there have been changes in some of the site numbers during the period covered by this Bulletin. The changes were necessitated by movement to a new site even though the instrument may have been moved only a few feet. The following list gives these station moves:

Former Site No.		Date of Closing	New Site No.	Date of Reopening
Brazil	9029	May 5, 1970	9039	May 7, 1970
Peru	9007	May 30, 1970	9027	June 1, 1970
S. Africa	9002	Dec. 17, 1970	9022	Jan. 5, 1971

SAO Laser Station Identification

Site Number	Location
7902	Olifantsfontein, South Africa
7907	Arequipa, Peru
7921	Mt. Hopkins, Arizona
7929	Natal, Brazil
7930	Dionysus, Greece

3. 1 Station Coordinates

LASER STATIONS

STA	LONG E	LAT (POS N)	H MSL	H ELL	DATUM	G H	NAME	DATE CDE
7826	038 57 30.36	+08 44 48.23	1921.2	1892.2	ADDN	-29.	ETHIOP	JA1573TK1
7902	028 14 53.909	-25 57 33.851	1543.88	1551.9	ARCC	+ 8.	CLIFTL	DC1572G61
7907	288 30 26.814	-16 27 55.085	2452.27	2486.5	SA69	+34.2	ARGUPL	JA0373TP3
7921	249 07 21.35	+31 41 02.87	2383.14	2370.4	NA27	-12.7	MHSAOL	JA0373041
7925	139 11 42.001	+36 00 08.696	855.29	854.8	TKYO	-0.5	DODLAS	JA1173T21
7929	324 50 08.660	-05 55 38.616	45.6	71.7	SA69	+26.1	NATALL	FB0873TP3
7930	023 55 59.991	+38 04 46.147	472.44	466.0	EU50	-6.4	DIOSLS	AU2572B11

S A O AND OTHER OPTICAL STATIONS

STA	LONG E	LAT (POS N)	H MSL	H ELL	DATUM	G H	NAME	DATE CDE
9002	028 14 53.91	-25 57 33.85	1544.1	1552.1	ARCC	+ 8.	OLFSFT	DC1572G61
9004	353 47 42.0891	+36 27 51.3666	26.00	- 9.0	EU50	-35.0	S.FERN	FB0973B11
9006	079 27 25.51	+29 21 38.97	1927.	1827.	EU50	-100.	NA.TAL	JE2172B11
9007	288 30 26.814	-16 27 55.085	2451.86	2486.1	SA69	+34.2	AREQUI	NV0172TP3
9012	203 44 24.08	+20 42 37.50	3034.14	3026.1	OHAW	- 8.	MAUI.H	NV0172S42
9021	249 07 21.35	+31 41 02.67	2383.12	2370.4	NA27	-12.7	MTHPBN	JA0373041
9022	028 14 54.351	-25 57 33.815	1543.34	1551.3	ARCC	+ 8.	OLIFTS	DC1572G61
9023	136 52 39.0156	-31 23 30.8163	137.91	136.9	AUGD	- 1.0	LAGOON	FB2073MP2
9025	139 11 43.159	+36 00 08.606	855.89	855.4	TKYO	-0.5	DODRAJ	JA1173T21
9027	288 30 26.578	-16 27 54.365	2450.23	2484.4	SA69	+34.2	AREQU2	JA0373TP3
9028	038 57 30.48	+08 44 47.23	1925.2	1896.2	ADDN	-29.	ETHIOP	SE0672TK1
9029	324 50 08.660	-05 55 38.616	45.34	71.4	SA69	+26.1	NATLBR	NV0172TP3
9030	023 56 00.130	+38 04 46.564	472.06	465.7	EU50	-6.4	DIOSBN	AU1772B11
9039	324 50 09.401	-05 55 38.616	41.6	67.7	SA69	+26.1	NATAL2	FB1573TP3
9040	358 30 10.44	+12 24 11.88	296.	.	ASIR	.	OUAGBN	JE2172 YO

LONG E	LONGITUDE EAST
LAT	LATITUDE
H MSL	MEAN SEA LEVEL HEIGHT
H ELL	ELLIPSOIDAL HEIGHT
G H	GEOID UNDULATION
CDE	DATUM CODE (LAST THREE CHARACTERS)

3.2 Time History Files

UT1

The difference between A.S and UT1 is expressed over 25- or 50-day intervals as a second degree polynomial of the form

$$A.S - UT1 = A_0 + A_1 (T - T_0) + A_2 (T - T_0)^2 \quad ,$$

where A.S - UT1 is in seconds, T is in Modified Julian Days (MJD), and T_0 is the beginning of the interval in MJD. The listing gives T_0, the interval (either 25 or 50 days), and the coefficients A_0, A_1, and A_2.

Clock Corrections

The clock-correction file gives the correction to A.S for each station.

The station-clock corrections are given as straight-line segments. The segments are specified by two times T_1 and T_2 and the corresponding corrections C_1 and C_2. The correction A.S - STA for a time T within the interval is given by

$$A.S - STA = \frac{T - T_1}{T_2 - T_1} (C_2 - C_1) + C_1 \quad ,$$

where A.S - STA and the C's are in seconds, and the T's are in MJD. The listing gives the station number, year, month, day, hour, minute, and second of T_1 and T_2, C_1 and C_2, and the time-accuracy code.

3.3 Coefficients for A.S - UT1

MJD	INTERVAL	YEAR	M	D	A0	A1	A2
40200	50	1968	12	10	6.9992317E+00	2.5587021E-03	-1.2562317E-06
40250	50	1969	1	29	7.1241715E+00	2.6096955E-03	6.4258524E-06
40300	50	1969	3	20	7.2698598E+00	3.1022034E-03	1.1934881E-08
40350	50	1969	5	9	7.4240364E+00	2.8990167E-03	-6.6505806E-06
40400	50	1969	6	28	7.5522970E+00	1.9273908E-03	5.7887906E-07
40450	50	1969	8	17	7.6501718E+00	2.1390599E-03	9.7481887E-06
40500	50	1969	10	6	7.7805765E+00	2.8622157E-03	6.6903742E-07
40550	50	1969	11	25	7.9247163E+00	2.9445376E-03	-3.5282170E-07
40600	50	1970	1	14	8.0711926F+00	2.7371500E-03	4.1451478E-06
40650	50	1970	3	5	8.2187073E+00	3.2240917E-03	-7.2612965E-07
40700	50	1970	4	24	8.3779081E+00	3.2458833E-03	-9.2363808E-06
40750	50	1970	6	13	8.5171191E+00	2.3386116E-03	-5.8353263E-06
40800	50	1970	8	2	8.6197877E+00	1.7498399E-03	7.6171554E-06
40850	50	1970	9	21	8.7261389E+00	2.7079800E-03	4.6054737E-06
40900	50	1970	11	10	8.8726687E+00	3.0954253E-03	-4.5499449E-06
40950	50	1970	12	30	9.0159238E+00	2.5853853E-03	-3.9493257E-07
41000	25	1971	2	18	9.1441454E+00	2.5127001E-03	7.8225433E-06
41025	25	1971	3	15	9.2112657E+00	3.5479501E-03	-9.1074737E-06
41050	50	1971	4	9	9.2932740E+00	3.1713471E-03	3.9504943E-07
41100	25	1971	5	29	9.4517811E+00	3.0035859E-03	-1.2618819E-05
41125	25	1971	6	23	9.5190744E+00	2.2190693E-03	5.2932524E-06
41150	25	1971	7	18	9.5778642E+00	2.5574090E-03	-5.4158487E-06
41175	25	1971	8	12	9.6385276E+00	2.1828628E-03	1.3381414E-05
41200	50	1971	9	6	9.7018485E+00	2.7342531E-03	9.0682717E-06
41250	50	1971	10	26	9.8605108E+00	3.8720920E-03	-8.4939023E-06
41300	25	1971	12	15	1.0032651E+01	2.5282375E-03	1.1612928E-05

3.4 Coefficients for A.S - STAT

STA	MJD	YEAR	M	D	H	M	S	C1	MJD	YEAR	M	D	H	M	S	C2	ACC
9002	40587	1970	1	1	0	0	0	8.035520	40937	1970	12	17	23	59	59	8.945312	1
9004	40587	1970	1	1	0	0	0	8.035520	40951	1970	12	31	23	59	59	8.981600	1
9006	40587	1970	1	1	0	0	0	8.035520	40951	1970	12	31	23	59	59	8.981600	1
9007	40587	1970	1	1	0	0	0	8.035520	40736	1970	5	30	23	59	59	8.424320	1
9027	40738	1970	6	1	0	0	0	8.426912	40951	1970	12	31	23	59	59	8.981600	1
9012	40587	1970	1	1	0	0	0	8.035520	40605	1970	1	19	0	0	0	8.082176	1
9012	40677	1970	4	1	0	0	0	8.268800	40951	1970	12	31	23	59	59	8.981600	2
9021	40587	1970	1	1	0	0	0	8.035520	40832	1970	9	3	23	0	0	8.673044	1
9021	40833	1970	9	4	0	0	0	8.673152	40951	1970	12	31	23	59	59	8.981600	1
9023	40587	1970	1	1	0	0	0	8.035520	40951	1970	12	31	23	59	59	8.981600	1
9025	40587	1970	1	1	0	0	0	8.035520	40951	1970	12	31	23	59	59	8.981600	1
9028	40587	1970	1	1	0	0	0	8.035520	40951	1970	12	31	23	59	59	8.981600	1
9029	40587	1970	1	1	0	0	0	8.035520	40617	1970	1	31	6	59	59	8.114036	1
9029	40617	1970	1	31	7	0	0	8.113036	40619	1970	2	2	2	4	59	8.117689	1
9029	40619	1970	2	2	2	5	0	8.118689	40682	1970	4	6	21	42	59	8.284105	1
9029	40682	1970	4	6	21	43	0	8.285283	40682	1970	4	6	22	0	59	8.285316	1
9029	40682	1970	4	6	22	1	0	8.284138	40711	1970	5	5	23	59	59	8.359520	1
9039	40713	1970	5	7	0	0	0	8.362112	40951	1970	12	31	23	59	59	8.981600	1
9030	40587	1970	1	1	0	0	0	8.035520	40818	1970	8	20	20	20	0	8.636468	1
9030	40818	1970	8	20	21	2	0	8.636544	40835	1970	9	6	19	4	59	8.680397	1
9030	40835	1970	9	6	19	5	0	8.682565	40835	1970	9	6	19	39	59	8.682628	1
9030	40835	1970	9	6	19	40	0	8.680460	40951	1970	12	31	23	59	59	8.981600	1

3.4 (Continued)

STA	MJD	YEAR	M	D	H	M	S	C1	MJD	YEAR	M	D	H	M	S	C2	ACC
9004	40952	1971	1	1	0	0	0	8.981600	41006	1971	2	24	19	49	59	9.123710	1
9004	41006	1971	2	24	19	50	0	10.123591	41007	1971	2	25	22	14	59	10.126444	1
9004	41007	1971	2	25	22	15	0	9.126563	41316	1971	12	31	23	59	59	9.927680	1
9006	40952	1971	1	1	0	0	0	8.981600	41316	1971	12	31	23	59	59	9.927680	1
9012	40952	1971	1	1	0	0	0	8.981600	41299	1971	12	14	18	59	59	9.883076	1
9012	41300	1971	12	15	13	45	0	9.885101	41306	1971	12	21	13	17	59	9.900604	2
9021	40952	1971	1	1	0	0	0	8.981600	41023	1971	3	13	5	17	59	9.166204	1
9021	41023	1971	3	13	12	36	0	9.166993	41316	1971	12	31	23	59	59	9.927680	1
9022	40956	1971	1	5	0	0	0	8.991968	41032	1971	3	22	1	29	59	9.189122	1
9022	41032	1971	3	22	1	30	0	9.233046	41034	1971	3	24	9	29	59	9.239094	1
9022	41034	1971	3	24	9	30	0	9.194590	41036	1971	3	26	20	49	59	9.202158	1
9022	41036	1971	3	26	20	50	0	9.201578	41059	1971	4	18	14	59	59	9.260564	1
9022	41059	1971	4	18	18	50	0	9.260978	41121	1971	6	19	6	24	59	9.420341	1
9022	41121	1971	6	19	18	45	0	9.421673	41131	1971	6	29	7	59	59	9.446432	1
9022	41131	1971	6	29	16	15	0	9.447323	41149	1971	7	17	22	59	59	9.494708	1
9022	41149	1971	7	17	23	0	0	9.494708	41151	1971	7	19	22	29	59	9.499838	2
9022	41151	1971	7	19	22	30	0	9.499838	41254	1971	10	30	15	59	59	9.766112	1
9022	41254	1971	10	30	19	0	0	9.766436	41316	1971	12	31	23	59	59	9.927680	1
9023	40952	1971	1	1	0	0	0	8.981600	41316	1971	12	31	23	59	59	9.927680	1
9025	40952	1971	1	1	0	0	0	8.981600	41316	1971	12	31	23	59	59	9.927680	1
9027	40952	1971	1	1	0	0	0	8.981600	41316	1971	12	31	23	59	59	9.927680	1
9028	40952	1971	1	1	0	0	0	8.981600	41039	1971	3	29	1	14	59	9.207239	1
9028	41039	1971	3	29	1	15	0	-60.802902	41041	1971	3	31	18	4	59	-60.795900	1
9028	41041	1971	3	31	18	5	0	9.214241	41041	1971	3	31	23	59	59	9.214880	1
9028	41042	1971	4	1	0	0	0	-60.795274	41042	1971	4	1	2	59	59	-60.794950	1
9028	41042	1971	4	1	3	0	0	9.215204	41126	1971	6	24	18	34	59	9.434615	1
9028	41127	1971	6	25	2	2	0	9.435420	41185	1971	8	22	17	20	59	9.587410	1
9028	41187	1971	8	24	16	15	0	9.592475	41279	1971	11	24	11	59	59	9.830480	1
9028	41279	1971	11	24	12	0	0	9.830480	41316	1971	12	31	23	59	59	9.927680	2
9030	40952	1971	1	1	0	0	0	8.981600	41105	1971	6	3	2	59	59	9.378500	1
9030	41107	1971	6	5	0	0	0	6.734240	41109	1971	6	7	20	10	59	6.741604	1
9030	41109	1971	6	7	20	11	0	9.441924	41111	1971	6	9	11	59	59	9.446224	1
9030	41111	1971	6	9	12	0	0	9.446154	41113	1971	6	11	23	59	59	9.452634	1
9030	41114	1971	6	12	0	0	0	9.453184	41124	1971	6	22	11	59	59	9.480400	1
9030	41124	1971	6	22	12	0	0	9.479730	41125	1971	6	23	22	49	59	9.483492	1
9030	41125	1971	6	23	22	50	0	9.132922	41126	1971	6	24	10	49	59	9.134218	1
9030	41126	1971	6	24	10	50	0	9.484708	41127	1971	6	25	11	59	59	9.487426	1
9030	41127	1971	6	25	12	0	0	9.487376	41128	1971	6	26	14	27	59	9.490234	1
9030	41128	1971	6	26	14	28	0	9.439354	41316	1971	12	31	23	59	59	9.927680	1
9039	40952	1971	1	1	0	0	0	8.981600	41316	1971	12	31	23	59	59	9.927680	1

3.4 (Continued)

STA	MJD	YEAR	M	D	H	M	S	C1	MJD	YEAR	M	D	H	M	S	C2	ACC
7902	40952	1971	1	1	0	0	0	8.981685	40982	1971	1	31	23	59	59	9.062037	1
7902	40983	1971	2	1	0	0	0	9.062028	41004	1971	2	22	1	59	59	9.116676	1
7902	41004	1971	2	22	2	0	0	9.116669	41006	1971	2	24	14	59	59	9.123257	1
7902	41006	1971	2	24	15	0	0	9.123254	41010	1971	2	28	23	59	59	9.134594	1
7902	41011	1971	3	1	0	0	0	9.134188	41032	1971	3	22	1	29	59	9.188782	1
7902	41032	1971	3	22	1	30	0	9.233046	41034	1971	3	24	9	29	59	9.239094	1
7902	41034	1971	3	24	9	30	0	9.194590	41036	1971	3	26	20	49	59	9.200998	1
7902	41036	1971	3	26	20	50	0	9.201217	41041	1971	3	31	23	59	59	9.214519	1
7902	41042	1971	4	1	0	0	0	9.214517	41059	1971	4	18	14	59	59	9.260201	1
7902	41059	1971	4	18	18	50	0	9.260610	41071	1971	4	30	23	59	59	9.292272	1
7902	41072	1971	5	1	0	0	0	9.292273	41092	1971	5	21	11	44	59	9.345382	1
7902	41092	1971	5	21	11	45	0	9.345754	41102	1971	5	31	23	59	59	9.372997	1
7902	41103	1971	6	1	0	0	0	9.372998	41121	1971	6	19	6	24	59	9.420347	1
7902	41121	1971	6	19	18	45	0	9.421681	41131	1971	6	29	7	59	59	9.446440	1
7902	41131	1971	6	29	8	0	0	9.446432	41131	1971	6	29	16	14	59	9.447323	1
7902	41131	1971	6	29	16	15	0	9.446997	41132	1971	6	30	23	59	59	9.450426	1
7902	41133	1971	7	1	0	0	0	9.450427	41142	1971	7	10	3	29	59	9.474133	1
7902	41142	1971	7	10	3	30	0	9.474133	41144	1971	7	12	0	39	59	9.479011	1
7902	41144	1971	7	12	0	40	0	9.479011	41149	1971	7	17	22	59	59	9.494383	1
7902	41149	1971	7	17	23	0	0	9.494383	41151	1971	7	19	0	10	59	9.497103	2
7902	41151	1971	7	19	0	11	0	9.497102	41151	1971	7	19	22	29	59	9.499512	2
7902	41151	1971	7	19	22	30	0	9.499513	41159	1971	7	27	23	34	59	9.520366	1
7902	41159	1971	7	27	23	35	0	9.520367	41161	1971	7	29	17	47	59	9.524926	1
7902	41161	1971	7	29	17	48	0	9.524926	41163	1971	7	31	23	59	59	9.530780	1
7902	41164	1971	8	1	0	0	0	9.530781	41184	1971	8	21	9	48	59	9.583681	1
7902	41184	1971	8	21	9	49	0	9.583684	41194	1971	8	31	23	59	59	9.611136	1
7902	41195	1971	9	1	0	0	0	9.611138	41223	1971	9	29	8	44	59	9.684659	1
7902	41223	1971	9	29	8	45	0	9.684974	41224	1971	9	30	23	59	59	9.689213	1
7902	41225	1971	10	1	0	0	0	9.689214	41243	1971	10	19	16	13	59	9.737623	1
7902	41243	1971	10	19	16	14	0	9.737623	41244	1971	10	20	1	45	59	9.738653	1
7902	41244	1971	10	20	1	46	0	9.738655	41254	1971	10	30	15	59	59	9.766112	1
7902	41254	1971	10	30	19	0	0	9.766437	41255	1971	10	31	23	59	59	9.769569	1
7902	41256	1971	11	1	0	0	0	9.769573	41285	1971	11	30	23	59	59	9.847333	1
7902	41286	1971	12	1	0	0	0	9.847337	41292	1971	12	7	16	19	59	9.864653	1
7902	41292	1971	12	7	16	20	0	9.864644	41316	1971	12	31	23	59	59	9.927680	1

3.4 (Continued)

STA	MJD	YEAR	M	D	H	M	S	C1	MJD	YEAR	M	D	H	M	S	C2	ACC
7907	40952	1971	1	1	0	0	0	8.981540	40982	1971	1	31	23	59	59	9.061892	1
7907	40983	1971	2	1	0	0	0	9.061895	40988	1971	2	6	23	59	59	9.077447	1
7907	40989	1971	2	7	0	0	0	9.077275	41010	1971	2	28	23	59	59	9.134299	1
7907	41011	1971	3	1	0	0	0	9.134264	41033	1971	3	23	15	59	59	9.193016	1
7907	41033	1971	3	23	16	0	0	9.192997	41041	1971	3	31	23	59	59	9.214597	1
7907	41042	1971	4	1	0	0	0	9.214594	41050	1971	4	9	4	59	59	9.235870	1
7907	41050	1971	4	9	5	0	0	9.236100	41071	1971	4	30	23	59	59	9.292584	1
7907	41072	1971	5	1	0	0	0	9.292586	41102	1971	5	31	23	59	59	9.372938	1
7907	41103	1971	6	1	0	0	0	9.372941	41132	1971	6	30	23	59	59	9.450701	1
7907	41133	1971	7	1	0	0	0	9.450703	41138	1971	7	6	20	10	10	9.465841	1
7907	41138	1971	7	6	20	30	0	9.465878	41163	1971	7	31	23	59	59	9.531056	1
7907	41164	1971	8	1	0	0	0	9.531059	41194	1971	8	31	23	59	59	9.611411	1
7907	41195	1971	9	1	0	0	0	9.611415	41224	1971	9	30	23	59	59	9.689175	1
7907	41225	1971	10	1	0	0	0	9.689178	41239	1971	10	15	5	6	59	9.726019	1
7907	41239	1971	10	15	5	7	0	9.726089	41240	1971	10	16	9	7	59	9.729114	1
7907	41240	1971	10	16	9	8	0	9.729044	41255	1971	10	31	23	59	59	9.769530	1
7907	41256	1971	11	1	0	0	0	9.769533	41269	1971	11	14	23	59	59	9.805821	1
7907	41270	1971	11	15	0	0	0	9.805823	41285	1971	11	30	23	59	59	9.847295	1
7907	41286	1971	12	1	0	0	0	9.847296	41299	1971	12	14	23	59	59	9.883584	1
7907	41300	1971	12	15	0	0	0	9.883584	41316	1971	12	31	23	59	59	9.927648	1
7921	40956	1971	1	5	7	24	0	8.992767	40993	1971	2	11	4	35	59	9.088369	1
7921	40993	1971	2	11	4	36	0	9.088369	41010	1971	2	28	23	59	59	9.134528	1
7921	41011	1971	3	1	0	0	0	9.134528	41041	1971	3	31	23	59	59	9.214880	1
7921	41042	1971	4	1	0	0	0	9.214883	41071	1971	4	30	23	59	59	9.292643	1
7921	41072	1971	5	1	0	0	0	9.292644	41102	1971	5	31	23	59	59	9.372996	1
7921	41103	1971	6	1	0	0	0	9.372996	41123	1971	6	21	3	51	59	9.425254	1
7921	41123	1971	6	21	3	52	0	9.425304	41124	1971	6	22	6	11	59	9.428148	1
7921	41124	1971	6	22	6	12	0	9.428198	41125	1971	6	23	18	4	59	9.432073	1
7921	41125	1971	6	23	18	5	0	9.431973	41129	1971	6	27	6	59	59	9.441144	1
7921	41129	1971	6	27	7	0	0	9.441194	41130	1971	6	28	23	29	59	9.445568	1
7921	41130	1971	6	28	23	30	0	9.445518	41132	1971	6	30	23	59	59	9.450756	1
7921	41133	1971	7	1	0	0	0	9.450756	41137	1971	7	5	7	39	59	9.461952	1
7921	41137	1971	7	5	7	40	0	9.462002	41138	1971	7	6	2	59	59	9.464090	1
7921	41138	1971	7	6	3	0	0	9.464040	41143	1971	7	11	9	48	59	9.477736	1
7921	41143	1971	7	11	9	49	0	9.477686	41143	1971	7	11	18	23	59	9.478613	1
7921	41143	1971	7	11	18	24	0	9.478663	41163	1971	7	31	23	59	59	9.531108	1
7921	41164	1971	8	1	0	0	0	9.531108	41194	1971	8	31	23	59	59	9.611460	1
7921	41195	1971	9	1	0	0	0	9.611456	41202	1971	9	8	12	29	59	9.630950	1
7921	41202	1971	9	8	12	30	0	9.630950	41207	1971	9	13	6	34	59	9.643271	1
7921	41207	1971	9	13	6	35	0	9.643221	41208	1971	9	14	3	7	59	9.645540	1
7921	41208	1971	9	14	3	8	0	9.645490	41224	1971	9	30	23	59	59	9.689216	1
7921	41225	1971	10	1	0	0	0	9.689215	41230	1971	10	6	9	1	59	9.703152	1
7921	41230	1971	10	6	9	2	0	9.703201	41243	1971	10	19	4	11	59	9.736375	1
7921	41243	1971	10	19	4	12	0	9.736325	41255	1971	10	31	23	59	59	9.769567	1
7921	41256	1971	11	1	0	0	0	9.769568	41269	1971	11	14	23	59	59	9.805856	1
7921	41270	1971	11	15	0	0	0	9.805859	41273	1971	11	18	6	59	59	9.814391	1
7921	41273	1971	11	18	7	0	0	9.814491	41285	1971	11	30	23	59	59	9.847431	1
7921	41286	1971	12	1	0	0	0	9.847428	41299	1971	12	14	23	59	59	9.883716	1
7921	41300	1971	12	15	0	0	0	9.883716	41304	1971	12	19	8	54	59	9.895047	1
7921	41304	1971	12	19	8	55	0	9.894953	41316	1971	12	31	23	59	59	9.927686	1

3.4 (Continued)

STA	MJD	YEAR	M	D	H	M	S	C1	MJD	YEAR	M	D	H	M	S	C2	ACC
7929	40952	1971	1	1	0	0	0	8.981582	40973	1971	1	22	20	44	59	9.038255	1
7929	40973	1971	1	22	20	45	0	9.038255	40974	1971	1	23	11	32	59	9.039853	1
7929	40974	1971	1	23	11	33	0	9.039849	40982	1971	1	31	23	59	59	9.061930	1
7929	40983	1971	2	1	0	0	0	9.061923	41010	1971	2	28	23	59	59	9.134499	1
7929	41011	1971	3	1	0	0	0	9.134465	41041	1971	3	31	23	59	59	9.214817	1
7929	41042	1971	4	1	0	0	0	9.214799	41071	1971	4	30	23	59	59	9.292559	1
7929	41072	1971	5	1	0	0	0	9.292562	41102	1971	5	31	23	59	59	9.372914	1
7929	41103	1971	6	1	0	0	0	9.372917	41132	1971	6	30	23	59	59	9.450677	1
7929	41133	1971	7	1	0	0	0	9.450680	41140	1971	7	8	1	20	59	9.468970	1
7929	41140	1971	7	8	1	21	0	9.468990	41140	1971	7	8	7	15	59	9.469629	1
7929	41140	1971	7	8	7	16	0	9.469609	41141	1971	7	9	0	21	59	9.471456	1
7929	41141	1971	7	9	0	22	0	9.471476	41141	1971	7	9	0	22	59	9.471477	1
7929	41141	1971	7	9	0	23	0	9.471457	41157	1971	7	25	13	9	59	9.514310	1
7929	41157	1971	7	25	13	10	0	9.514382	41163	1971	7	31	23	59	59	9.531104	1
7929	41164	1971	8	1	0	0	0	9.531104	41194	1971	8	31	23	59	59	9.611456	1
7929	41195	1971	9	1	0	0	0	9.611462	41209	1971	9	15	23	59	59	9.650342	1
7929	41210	1971	9	16	0	0	0	9.650454	41224	1971	9	30	23	59	59	9.689334	1
7929	41225	1971	10	1	0	0	0	9.689337	41255	1971	10	31	23	59	59	9.769689	1
7929	41256	1971	11	1	0	0	0	9.769693	41280	1971	11	25	21	21	59	9.834209	1
7929	41280	1971	11	25	21	22	0	9.834109	41281	1971	11	26	5	9	59	9.834951	1
7929	41281	1971	11	26	5	10	0	9.835051	41285	1971	11	30	23	59	59	9.847453	1
7929	41286	1971	12	1	0	0	0	9.847455	41316	1971	12	31	23	59	59	9.927807	1
7930	40952	1971	1	1	0	0	0	8.981483	40956	1971	1	5	16	19	59	8.993615	1
7930	40956	1971	1	5	16	20	0	8.993535	40956	1971	1	5	16	29	59	8.993553	1
7930	40956	1971	1	5	16	30	0	8.993633	40969	1971	1	18	17	39	59	9.027455	1
7930	40969	1971	1	18	17	40	0	9.027395	40969	1971	1	18	17	49	59	9.027413	1
7930	40969	1971	1	18	17	50	0	9.027473	40970	1971	1	19	3	49	59	9.028553	1
7930	40970	1971	1	19	3	50	0	9.028483	40970	1971	1	19	3	54	59	9.028492	1
7930	40970	1971	1	19	3	55	0	9.028562	40971	1971	1	20	16	59	59	9.032567	1
7930	40971	1971	1	20	17	0	0	9.032497	40973	1971	1	22	0	59	59	9.035953	1
7930	40973	1971	1	22	1	0	0	9.036023	40976	1971	1	25	15	59	59	9.045419	1
7930	40976	1971	1	25	16	0	0	9.045359	40977	1971	1	26	4	59	59	9.046763	1
7930	40977	1971	1	26	5	0	0	9.046823	40978	1971	1	27	0	59	59	9.048983	1
7930	40978	1971	1	27	1	0	0	9.048913	40978	1971	1	27	22	59	59	9.051289	1
7930	40978	1971	1	27	23	0	0	9.051359	40979	1971	1	28	3	59	59	9.051899	1
7930	40979	1971	1	28	4	0	0	9.051799	40981	1971	1	30	17	59	59	9.058495	1
7930	40981	1971	1	30	18	0	0	9.058595	40982	1971	1	31	23	59	59	9.061835	1
7930	40983	1971	2	1	0	0	0	9.061823	40983	1971	2	1	15	59	59	9.063551	1
7930	40983	1971	2	1	16	0	0	9.063471	40984	1971	2	2	19	59	59	9.066495	1
7930	40984	1971	2	2	20	0	0	9.066575	41008	1971	2	26	23	59	59	9.129215	1
7930	41009	1971	2	27	0	0	0	9.129175	41009	1971	2	27	20	59	59	9.131443	1
7930	41009	1971	2	27	21	0	0	9.131483	41010	1971	2	28	23	59	59	9.134399	1

3.4 (Continued)

STA	MJD	YEAR	M	D	H	M	S	C1	MJD	YEAR	M	D	H	M	S	C2	ACC
7930	41011	1971	3	1	0	0	0	9.134365	41027	1971	3	17	16	59	59	9.177673	1
7930	41027	1971	3	17	17	0	0	9.177723	41029	1971	3	19	17	27	59	9.182957	1
7930	41029	1971	3	19	17	28	0	9.182907	41036	1971	3	26	11	59	59	9.200461	1
7930	41036	1971	3	26	12	0	0	9.200411	41039	1971	3	29	20	59	59	9.209159	1
7930	41039	1971	3	29	21	0	0	9.209209	41041	1971	3	31	23	59	59	9.214717	1
7930	41042	1971	4	1	0	0	0	9.214699	41069	1971	4	28	23	59	59	9.287275	1
7930	41070	1971	4	29	0	0	0	9.287285	41071	1971	4	30	18	17	59	9.291853	1
7930	41071	1971	4	30	18	18	0	9.291843	41071	1971	4	30	23	59	59	9.292459	1
7930	41072	1971	5	1	0	0	0	9.292462	41078	1971	5	7	18	59	59	9.310066	1
7930	41078	1971	5	7	19	0	0	9.310016	41081	1971	5	10	19	20	59	9.317830	1
7930	41081	1971	5	10	19	21	0	9.317880	41082	1971	5	11	17	59	59	9.320326	1
7930	41082	1971	5	11	18	0	0	9.320276	41083	1971	5	12	18	17	59	9.322900	1
7930	41083	1971	5	12	18	18	0	9.322950	41087	1971	5	16	17	59	59	9.333286	1
7930	41087	1971	5	16	18	0	0	9.333306	41088	1971	5	17	19	27	59	9.336056	1
7930	41088	1971	5	17	19	28	0	9.336036	41101	1971	5	30	17	59	59	9.369574	1
7930	41101	1971	5	30	18	0	0	9.369554	41102	1971	5	31	18	59	59	9.372254	1
7930	41102	1971	5	31	19	0	0	9.372274	41103	1971	6	1	11	59	59	9.374110	1
7930	41103	1971	6	1	12	0	0	9.374140	41103	1971	6	1	21	9	59	9.375130	1
7930	41103	1971	6	1	21	10	0	9.375100	41105	1971	6	3	7	59	59	9.378862	1
7930	41107	1971	6	5	0	0	0	6.734240	41109	1971	6	7	20	10	59	6.741604	1
7930	41109	1971	6	7	20	11	0	9.441924	41111	1971	6	9	11	59	59	9.446224	1
7930	41111	1971	6	9	12	0	0	9.446154	41113	1971	6	11	23	59	59	9.452634	1
7930	41114	1971	6	12	0	0	0	9.452584	41124	1971	6	22	11	59	0	9.479798	1
7930	41124	1971	6	22	12	0	0	9.479730	41125	1971	6	23	22	49	59	9.483492	1
7930	41125	1971	6	23	22	50	0	9.132922	41126	1971	6	24	10	49	59	9.134218	1
7930	41126	1971	6	24	10	50	0	9.484708	41127	1971	6	25	11	59	59	9.487426	1
7930	41127	1971	6	25	12	0	0	9.487376	41128	1971	6	26	14	27	59	9.490234	1
7930	41128	1971	6	26	14	28	0	9.439134	41130	1971	6	28	15	32	59	9.444435	1
7930	41130	1971	6	28	15	33	0	9.444735	41132	1971	6	30	23	59	59	9.450832	1
7930	41133	1971	7	1	0	0	0	9.450832	41135	1971	7	3	11	59	59	9.457312	1
7930	41135	1971	7	3	12	0	0	9.457232	41139	1971	7	7	11	59	59	9.467600	1
7930	41144	1971	7	12	0	0	0	9.479344	41145	1971	7	13	18	38	59	9.483950	1
7930	41145	1971	7	13	18	39	0	9.483870	41163	1971	7	31	23	59	59	9.531104	1
7930	41164	1971	8	1	0	0	0	9.531104	41168	1971	8	5	17	59	59	9.543416	1
7930	41168	1971	8	5	18	0	0	9.543346	41169	1971	8	6	19	56	59	9.546149	1
7930	41169	1971	8	6	19	57	0	9.546219	41175	1971	8	12	17	59	59	9.561560	1
7930	41175	1971	8	12	18	0	0	9.561520	41177	1971	8	14	19	39	59	9.566884	1
7930	41177	1971	8	14	19	40	0	9.566924	41194	1971	8	31	23	59	59	9.611456	1
7930	41195	1971	9	1	0	0	0	9.611467	41204	1971	9	10	17	59	59	9.636739	1
7930	41204	1971	9	10	18	0	0	9.636689	41206	1971	9	12	11	59	59	9.641225	1
7930	41206	1971	9	12	12	0	0	9.641175	41208	1971	9	14	12	29	59	9.646413	1
7930	41208	1971	9	14	12	30	0	9.646513	41209	1971	9	15	16	59	59	9.649591	1
7930	41209	1971	9	15	17	0	0	9.649611	41210	1971	9	16	17	29	59	9.652257	1
7930	41210	1971	9	16	17	30	0	9.652237	41224	1971	9	30	23	59	59	9.689227	1
7930	41225	1971	10	1	0	0	0	9.689230	41255	1971	10	31	23	59	59	9.769582	1
7930	41256	1971	11	1	0	0	0	9.769586	41273	1971	11	18	0	14	59	9.813677	1
7930	41273	1971	11	18	0	15	0	9.813657	41273	1971	11	18	19	51	59	9.815776	1
7930	41273	1971	11	18	19	52	0	9.815796	41274	1971	11	19	19	51	59	9.818388	1
7930	41274	1971	11	19	19	52	0	9.818308	41275	1971	11	20	3	48	59	9.819166	1
7930	41275	1971	11	20	3	49	0	9.819246	41285	1971	11	30	23	59	59	9.847346	1
7930	41286	1971	12	1	0	0	0	9.847348	41316	1971	12	31	23	59	59	9.927700	1

3.5 Pole Positions*

BESSEL.YR	MO DY	EPOCH	X	Y	SOURCE
1962.00	01 01	37665.	-.009	.297	IPMS ARPT64
1962.05	01 19	37683.	.008	.309	IPMS ARPT64
1962.10	02 07	37702.	.027	.314	IPMS ARPT64
1962.15	02 25	37720.	.047	.312	IPMS ARPT64
1962.20	03 15	37738.	.071	.304	IPMS ARPT64
1962.25	04 02	37756.	.095	.290	IPMS ARPT64
1962.30	04 21	37775.	.120	.271	IPMS ARPT64
1962.35	05 09	37793.	.142	.246	IPMS ARPT64
1962.40	05 27	37811.	.162	.214	IPMS ARPT64
1962.45	06 14	37829.	.173	.175	IPMS ARPT64
1962.50	07 03	37848.	.171	.132	IPMS ARPT64
1962.55	07 21	37866.	.157	.092	IPMS ARPT64
1962.60	08 08	37884.	.128	.068	IPMS ARPT64
1962.65	08 26	37902.	.094	.060	IPMS ARPT64
1962.70	09 14	37921.	.056	.067	IPMS ARPT64
1962.75	10 02	37939.	.017	.083	IPMS ARPT64
1962.80	10 20	37957.	-.019	.104	IPMS ARPT64
1962.85	11 07	37975.	-.054	.128	IPMS ARPT64
1962.90	11 26	37994.	-.086	.160	IPMS ARPT64
1962.95	12 14	38012.	-.110	.200	IPMS ARPT64
1963.00	01 01	38030.	-.121	.248	IPMS ARPT65
1963.05	01 19	38048.	-.119	.295	IPMS ARPT65
1963.10	02 07	38067.	-.105	.329	IPMS ARPT65
1963.15	02 25	38085.	-.076	.356	IPMS ARPT65
1963.20	03 15	38103.	-.038	.376	IPMS ARPT65
1963.25	04 02	38121.	.009	.388	IPMS ARPT65
1963.30	04 21	38140.	.070	.387	IPMS ARPT65
1963.35	05 09	38158.	.134	.375	IPMS ARPT65
1963.40	05 27	38176.	.191	.349	IPMS ARPT65
1963.45	06 14	38194.	.239	.307	IPMS ARPT65
1963.50	07 03	38213.	.274	.251	IPMS ARPT65
1963.55	07 21	38231.	.301	.193	IPMS ARPT65
1963.60	08 08	38249.	.281	.139	IPMS ARPT65
1963.65	08 26	38267.	.237	.091	IPMS ARPT65
1963.70	09 14	38286.	.176	.046	IPMS ARPT65
1963.75	10 02	38304.	.112	.008	IPMS ARPT65
1963.80	10 20	38322.	.048	-.020	IPMS ARPT65
1963.85	11 07	38340.	-.011	.005	IPMS ARPT65
1963.90	11 26	38359.	-.069	.041	IPMS ARPT65
1963.95	12 14	38377.	-.122	.078	IPMS ARPT65

*Pole positions for 1962–1969 have been included for the convenience of the user.

3.5 (Continued)

1964.00	01 01	38395.	-.171	.120	IPMS	ARPT66
1964.05	01 19	38413.	-.206	.168	IPMS	ARPT66
1964.10	02 07	38432.	-.194	.230	IPMS	ARPT66
1964.15	02 25	38450.	-.169	.294	IPMS	ARPT66
1964.20	03 14	38468.	-.139	.353	IPMS	ARPT66
1964.25	04 01	38486.	-.101	.412	IPMS	ARPT66
1964.30	04 20	38505.	-.055	.455	IPMS	ARPT66
1964.35	05 08	38523.	.004	.467	IPMS	ARPT66
1964.40	05 26	38541.	.074	.459	IPMS	ARPT66
1964.45	06 13	38559.	.164	.436	IPMS	ARPT66
1964.50	07 02	38578.	.214	.394	IPMS	ARPT66
1964.55	07 20	38596.	.240	.339	IPMS	ARPT66
1964.60	08 07	38614.	.241	.275	IPMS	ARPT66
1964.65	08 25	38632.	.239	.219	IPMS	ARPT66
1964.70	09 13	38651.	.255	.168	IPMS	ARPT66
1964.75	10 01	38669.	.250	.123	IPMS	ARPT66
1964.80	10 19	38687.	.219	.085	IPMS	ARPT66
1964.85	11 06	38705.	.161	.060	IPMS	ARPT66
1964.90	11 25	38724.	.099	.046	IPMS	ARPT66
1964.95	12 13	38742.	.042	.043	IPMS	ARPT66
1965.00	01 01	38761.	-.012	.049	IPMS	ARPT67
1965.05	01 19	38779.	-.067	.069	IPMS	ARPT67
1965.10	02 07	38798.	-.120	.103	IPMS	ARPT67
1965.15	02 25	38816.	-.160	.153	IPMS	ARPT67
1965.20	03 15	38834.	-.185	.226	IPMS	ARPT67
1965.25	04 02	38852.	-.196	.286	IPMS	ARPT67
1965.30	04 21	38871.	-.194	.334	IPMS	ARPT67
1965.35	05 09	38889.	-.174	.374	IPMS	ARPT67
1965.40	05 27	38907.	-.130	.408	IPMS	ARPT67
1965.45	06 14	38925.	-.072	.434	IPMS	ARPT67
1965.50	07 03	38944.	-.003	.444	IPMS	ARPT67
1965.55	07 21	38962.	.071	.433	IPMS	ARPT67
1965.60	08 08	38980.	.127	.399	IPMS	ARPT67
1965.65	08 26	38998.	.168	.349	IPMS	ARPT67
1965.70	09 14	39017.	.201	.303	IPMS	ARPT67
1965.75	10 02	39035.	.221	.259	IPMS	ARPT67
1965.80	10 20	39053.	.227	.221	IPMS	ARPT67
1965.85	11 07	39071.	.220	.186	IPMS	ARPT67
1965.90	11 26	39090.	.194	.156	IPMS	ARPT67
1965.95	12 14	39108.	.138	.131	IPMS	ARPT67

3.5 (Continued)

1966.00	01 01	39126.	.075	.114	IPMS	ARPT68
1966.05	01 19	39144.	.033	.103	IPMS	ARPT68
1966.10	02 07	39163.	.000	.098	IPMS	ARPT68
1966.15	02 25	39181.	-.029	.100	IPMS	ARPT68
1966.20	03 15	39199.	-.058	.108	IPMS	ARPT68
1966.25	04 02	39217.	-.086	.124	IPMS	ARPT68
1966.30	04 21	39236.	-.105	.149	IPMS	ARPT68
1966.35	05 09	39254.	-.116	.181	IPMS	ARPT68
1966.40	05 27	39272.	-.119	.215	IPMS	ARPT68
1966.45	06 14	39290.	-.115	.255	IPMS	ARPT68
1966.50	07 03	39309.	-.104	.298	IPMS	ARPT68
1966.55	07 21	39327.	-.086	.330	IPMS	ARPT68
1966.60	08 08	39345.	-.057	.344	IPMS	ARPT68
1966.65	08 26	39363.	-.010	.345	IPMS	ARPT68
1966.70	09 14	39382.	.052	.337	IPMS	ARPT68
1966.75	10 02	39400.	.096	.324	IPMS	ARPT68
1966.80	10 20	39418.	.117	.308	IPMS	ARPT68
1966.85	11 07	39436.	.125	.291	IPMS	ARPT68
1966.90	11 26	39455.	.123	.273	IPMS	ARPT68
1966.95	12 14	39473.	.115	.253	IPMS	ARPT68
1967.00	01 01	39491.	.098	.234	IPMS	ARPT69
1967.05	01 19	39509.	.075	.214	IPMS	ARPT69
1967.10	02 07	39528.	.053	.193	IPMS	ARPT69
1967.15	02 25	39546.	.032	.176	IPMS	ARPT69
1967.20	03 15	39564.	.013	.164	IPMS	ARPT69
1967.25	04 02	39582.	.000	.156	IPMS	ARPT69
1967.30	04 21	39601.	-.006	.153	IPMS	ARPT69
1967.35	05 09	39619.	-.007	.153	IPMS	ARPT69
1967.40	05 27	39637.	-.002	.155	IPMS	ARPT69
1967.45	06 14	39655.	.011	.159	IPMS	ARPT69
1967.50	07 03	39674.	.037	.166	IPMS	ARPT69
1967.55	07 21	39692.	.055	.174	IPMS	ARPT69
1967.60	08 08	39710.	.047	.184	IPMS	ARPT69
1967.65	08 26	39728.	.026	.195	IPMS	ARPT69
1967.70	09 14	39747.	.006	.207	IPMS	ARPT69
1967.75	10 02	39765.	-.013	.221	IPMS	ARPT69
1967.80	10 20	39783.	-.031	.237	IPMS	ARPT69
1967.85	11 07	39801.	-.049	.253	IPMS	ARPT69
1967.90	11 26	39820.	-.062	.273	IPMS	ARPT69
1967.95	12 24	39838.	-.064	.292	IPMS	ARPT69

3.5 (Continued)

1968.00	01 01	39856.	-.055	.305	IPMS	ARPT70
1968.05	01 19	39874.	-.037	.310	IPMS	ARPT70
1968.10	02 07	39893.	-.014	.309	IPMS	ARPT70
1968.15	02 25	39911.	.009	.302	IPMS	ARPT70
1968.20	03 14	39929.	.030	.290	IPMS	ARPT70
1968.25	04 01	39947.	.048	.274	IPMS	ARPT70
1968.30	04 20	39966.	.057	.259	IPMS	ARPT70
1968.35	05 08	39984.	.059	.244	IPMS	ARPT70
1968.40	05 26	40002.	.061	.229	IPMS	ARPT70
1968.45	06 13	40020.	.067	.214	IPMS	ARPT70
1968.50	07 02	40039.	.089	.198	IPMS	ARPT70
1968.55	07 20	40057.	.104	.183	IPMS	ARPT70
1968.60	08 07	40075.	.095	.169	IPMS	ARPT70
1968.65	08 25	40093.	.060	.160	IPMS	ARPT70
1968.70	09 13	40112.	.016	.158	IPMS	ARPT70
1968.75	10 01	40130.	-.022	.162	IPMS	ARPT70
1968.80	10 19	40148.	-.053	.175	IPMS	ARPT70
1968.85	11 06	40166.	-.084	.201	IPMS	ARPT70
1968.90	11 25	40185.	-.111	.236	IPMS	ARPT70
1968.95	12 13	40203.	-.127	.268	IPMS	ARPT70
1969.00	01 01	40222.	-.123	.290	IPMS	ARPT71
1969.05	01 19	40240.	-.106	.306	IPMS	ARPT71
1969.10	02 07	40259.	-.099	.323	IPMS	ARPT71
1969.15	02 25	40277.	-.085	.344	IPMS	ARPT71
1969.20	03 15	40295.	-.036	.372	IPMS	ARPT71
1969.25	04 02	40313.	.015	.392	IPMS	ARPT71
1969.30	04 21	40332.	.052	.396	IPMS	ARPT71
1969.35	05 09	40350.	.090	.387	IPMS	ARPT71
1969.40	05 27	40368.	.126	.366	IPMS	ARPT71
1969.45	06 14	40386.	.158	.337	IPMS	ARPT71
1969.50	07 03	40405.	.180	.302	IPMS	ARPT71
1969.55	07 21	40423.	.188	.257	IPMS	ARPT71
1969.60	08 08	40441.	.184	.211	IPMS	ARPT71
1969.65	08 26	40459.	.165	.167	IPMS	ARPT71
1969.70	09 14	40478.	.125	.135	IPMS	ARPT71
1969.75	10 02	40496.	.079	.114	IPMS	ARPT71
1969.80	10 20	40514.	.036	.106	IPMS	ARPT71
1969.85	11 07	40532.	-.014	.106	IPMS	ARPT71
1969.90	11 26	40551.	-.069	.113	IPMS	ARPT71
1969.95	12 14	40569.	-.116	.133	IPMS	ARPT71

3.5 (Continued)

1970.00	01 01	40587.	-.157	.169	IPMS ARPT72
1970.05	01 19	40605.	-.180	.219	IPMS ARPT72
1970.10	02 07	40624.	-.180	.276	IPMS ARPT72
1970.15	02 25	40642.	-.161	.332	IPMS ARPT72
1970.20	03 15	40660.	-.131	.382	IPMS ARPT72
1970.25	04 02	40678.	-.098	.422	IPMS ARPT72
1970.30	04 21	40697.	-.063	.450	IPMS ARPT72
1970.35	05 09	40715.	-.026	.467	IPMS ARPT72
1970.40	05 27	40733.	.021	.463	IPMS ARPT72
1970.45	06 14	40751.	.092	.436	IPMS ARPT72
1970.55	07 03	40770.	.159	.395	IPMS ARPT72
1970.55	07 21	40788.	.209	.350	IPMS ARPT72
1970.60	08 08	40806.	.241	.302	IPMS ARPT72
1970.65	08 26	40824.	.249	.252	IPMS ARPT72
1970.70	09 14	40843.	.234	.198	IPMS ARPT72
1970.75	10 02	40861.	.204	.150	IPMS ARPT72
1970.80	10 20	40879.	.166	.113	IPMS ARPT72
1970.85	11 07	40897.	.121	.079	IPMS ARPT72
1970.90	11 26	40916.	.072	.045	IPMS ARPT72
1970.95	12 14	40934.	.024	.014	IPMS ARPT72
1971.00	01 01	40952.	-.045	.020	IPMS MN0171
1971.05	01 19	40970.	-.127	.052	IPMS MN0371
1971.10	02 07	40989.	-.211	.097	IPMS MN0371
1971.15	02 25	41007.	-.242	.149	IPMS MN0471
1971.20	03 15	41025.	-.225	.204	IPMS MN0471
1971.25	04 02	41043.	-.184	.270	IPMS MN0571
1971.30	04 21	41062.	-.135	.340	IPMS MN0571
1971.35	05 09	41080.	-.078	.389	IPMS MN0671
1971.40	05 27	41098.	-.027	.443	IPMS MN0771
1971.45	06 14	41116.	.026	.478	IPMS MN0871
1971.50	07 03	41135.	.086	.482	IPMS MN0871
1971.55	07 21	41153.	.150	.468	IPMS MN0971
1971.60	08 08	41171.	.214	.444	IPMS MN0971
1971.65	08 26	41189.	.261	.409	IPMS MN1071
1971.70	09 14	41208.	.270	.337	IPMS MN1171
1971.75	10 02	41226.	.256	.276	IPMS MN1171
1971.80	10 20	41244.	.220	.236	IPMS MN1271
1971.85	11 07	41262.	.177	.201	IPMS MN1271
1971.90	11 26	41281.	.143	.166	IPMS MN0172
1971.95	12 14	41299.	.114	.122	IPMS MN0172

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5. ABBREVIATIONS

AMS	U. S. ARMY MAP SERVICE (NOW USATOPOCOM)
AGU	AMERICAN GEOPHYSICAL UNION
A.S	SAO UNIFORM TIME SYSTEM
BIH	BUREAU INTERNATIONAL DE L≠HEURE
BIPM	BUREAU INTERNATIONAL DES POIS ET MESURES
CBSG	CENTRAL BUREAU FOR SATELLITE GEODESY
C&GS	U.S. COAST AND GEODETIC SURVEY
CNES	CENTRE NATIONAL D≠ETUDES SPATIALES
COSPAR	COMMITTEE ON SPACE RESEARCH
DSIF	DEEP SPACE INSTRUMENTATION FACILITY (NOW DSN)
DSN	DEEP SPACE NETWORK (JPL)
EDP	SAO EARTH DYNAMICS PROGRAM
EOPAP	NASA EARTH AND OCEAN PHYSICS APPLICATIONS PROGRAM
EPSOC	EARTH PHYSICS SATELLITE OBSERVATION CAMPAIN
GRGS	GROUPE DE RECHERCHES DE GEODESIE SPATIALE
GSFC	GODDARD SPACE FLIGHT CENTER
IAG	INTERNATIONAL ASSOCIATION OF GEODESY
IAGS	INTER-AMERICAN GEODETIC SURVEY
IAU	INTERNATIONAL ASTRONOMICAL UNION
IGM	INSTITUTO GEOGRAFICA MILITAR
IGN	INSTITUT GEOGRAPHIQUE NATIONALE (FRANCE)
IPMS	INTERNATIONAL POLAR MOTION SERVICE
ISAGEX	INTERNATIONAL SATELLITE GEODESY EXPERIMENT
IUGG	INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS
IUWDS	INTERNATIONAL URSIGRAM AND WORLD DAYS SERVICE
MJD	MODIFIED JULIAN DAYS
MSL	MEAN SEA LEVEL
MOTS	MINITRACK OPTICAL TRACKING SYSTEM
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NBS	U.S. NATIONAL BUREAU OF STANDARDS
NGC	NORDIC GEODETIC COMMISSION
NGSP	NATIONAL GEODETIC SATELLITE PROGRAM
NOAA	NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOS	NATIONAL OCEANIC SURVEY (FORMER COAST AND GEODETIC SURVEY)
NSF	NATIONAL SCIENCE FOUNDATION
NTU	NATIONAL TECHNICAL UNIVERSITY, ATHENS, GREECE
NWL	U.S. NAVAL WEAPONS LABORATORY
OTV	ON TIME VALUE
PREDAT	PRECISION CONTROL BULLETINS (1967)
REUN	RESEAU EUROPEEN UNIFIE DE NIVELLEMENT
SAO	SMITHSONIAN ASTROPHYSICAL OBSERVATORY
SECOR	SEQUENTIAL COLLATION OF RANGE SYSTEM
STADAD	SATELLITE TRACKING AND DATA ACQUISITION DEPT. (SAO)
STADAN	SATELLITE TRACKING AND DATA ACQUISITION NETWORK (GSFC)
STAT	STATION TIME AS PRESENTED IN THE DATA
STP	SATELLITE TRACKING PROGRAM
USNO	UTC(USNO)

USNO	UNITED STATES NAVAL OBSERVATORY
UTC	COORDINATED UNIVERSAL TIME SYSTEM
UT1	UNIVERSAL TIME SYSTEM CORRECTED FOR THE POLAR MOTION
UT2	UNIVERSAL TIME SYSTEM CORRECTED FOR VARIATIONS IN THE EARTH ROTATION
VLBI	VERY LONG-BASELINE INTERFEROMETRY
VLF	PHASE OF THE VERY LOW FREQUENCY RADIO SOURCE
WEST	WEST EUROPEAN SATELLITE TRIANGULATION PROGRAM